

VII

POST-TRAUMATIC GROWTH DISTURBANCE OF THE ANKLE TREATED BY THE LANGENSKIÖLD PROCEDURE

Evaluation by radiography, roentgen stereogrammetry, scintimetry and histology

Case report

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ABSTRACT

Progressive growth retardation and varus tilting were observed in a case with an ankle fracture of supination-adduction type. The patient was operated with the Langenskiöld procedure because of her deformity.

Preoperative evaluation was performed with radiography including tomography, roentgen stereophotogrammetry, and scintimetry.

Preoperative radiograms showed a bony bridge medially, an asymmetric condensation line as a sign growth mainly laterally and posteriorly, and a minimal step of the physis and the tibial joint area postero-medially. Preoperative roentgen stereophotogrammetric analysis showed decreasing growth rates especially medially in the distal tibia, but also laterally and in the distal fibula. Scintimetry showed reduced activity at the injured side. The evidence of growth in the distal tibia indicated the existence of an osseofibrous bridge and not a bony fusion between the epiphysis and the metaphysis.

Microscopical investigation of the removed osseofibrous bridge showed plexiform and irregular bone formation; at the metaphyseal side areas with newly formed callus, fibrous tissue, and around the osseofibrous bridge a wide growth plate.

Postoperative roentgen stereophotogrammetric analysis showed that the epiphysis had moved about 0.7 mm distally at the medial side and 0.25 mm at the lateral side after the operation. Further examinations post-operatively showed a two-step recovery. During the first three months the growth rates were higher medially, during the next four months they were higher laterally, and during the following periods higher growth rates medially were found, almost corresponding to the growth rate on the intact side.

Conclusion:

This case report demonstrates the value of the roentgen stereophotogrammetric method which gives an early detection of a growth distur-

bance. The postoperative evaluation is facilitated and an eventual recurrence of the deformity will be detected. With the present knowledge of the nature of a progressive growth retardation after physeal fracture in the younger child, an operative procedure in order to restore normal growth will be performed earlier than in the present case.

INTRODUCTION

Growth disturbance after physeal fractures was described in the eighteenth (39) and nineteenth century (6,7,47), although the existence of physeal fractures was not generally accepted (12). In 1867 Bouchut (5) described a varus deformity after physeal fracture. Later a similar deformity was found after adduction injuries according to McFarland (31). The anatomy, genetic production, treatment, and complications of adduction injuries were focused in several studies (17,18,27).

Surgical correction of growth deformity of the ankle was described by Ollier (36,37). Rose (40) treated the varus deformity by resection of the fibula. Davies-Colley (13,14) and Poland (38) found this operation insufficient and added an osteotomy of the distal tibia. Later on osteotomy became the treatment of choice of this deformity (2,3,18,31). Langenskiöld (27) recommended Phemister epiphyseodesis of the distal fibula; in some cases also of the distal tibia.

Several authors (4,9,15,16,19,20,23,32,34,35,47) studied the morphology of the growth plate after physeal trauma, the development of bony bridging and its effect on longitudinal growth (15,23,34,47).

Based on a clinical observation of a case with spontaneous disappearance of a radiographical bony bridge after an osteotomy, surgical resection of bony bridges and fat interposition was successfully tried

in several cases (28,29,30). The experimental basis for the operation was comprehensively investigated by Österman (48).

An earlier investigation (25) studied the growth pattern after supination-adduction ankle fractures in ten cases, one of which showed an initial and progressive growth retardation resulting in a varus deformity. About 15 months after fracture the Langenskiöld procedure was performed. This case report concerns preoperative investigations such as radiography, tomography, scintimetry, roentgen stereophotogrammetry, and microscopical investigation of resected parts of the osseofibrous bridge at the operation. The results of the operation were judged from radiography and roentgen stereophotogrammetric analysis (1,24,25,26,42,43).

METHODS

Roentgen stereophotogrammetry

In order to register the growth pattern tantalum balls diameter 0.5 mm were inserted at fracture healing. Further two bone markers were inserted during the Langenskiöld operation. Roentgen stereophotogrammetric examinations (1,24,25,26,42,43) were performed with intervals of one to four months. Daily longitudinal growth (24) and movements of the distal tibial epiphysis on the fractured side about the cardinal axis were analysed (24).

Scintimetry

The scintimetric analysis was performed using Tc^{99m} -methylenediphosphate (Tc^{99m} -MDP)(8).

Histology

The biopsies from the osseofibrous bridge were decalcified, sectioned, and stained with haemotoxylin-eosin.

CASE REPORT

A six years old girl fell from a swing and suffered an ankle fracture. Radiographs showed a supination-adduction injury Stage II (17). According to Salter and Harris (41) Type I injury through the lateral malleolus, and in addition, a minimal fragment at the tip of the lateral malleolus. The medial malleolar fracture ran in a zigzag pattern (Z or Type IV), detaching the medial malleolus with a minimal metaphyseal fragment attached to it. Proximal and medial displacement of about 2-3 mm, and a considerable rotation of the medial malleolus were registered (Fig. 1 a and b). Due to blistering of the skin, closed reduction and percutaneous pinning medially was performed. Postoperative radiograms showed almost no displacement. Plaster fixation for about five weeks. The fracture healed without problems.

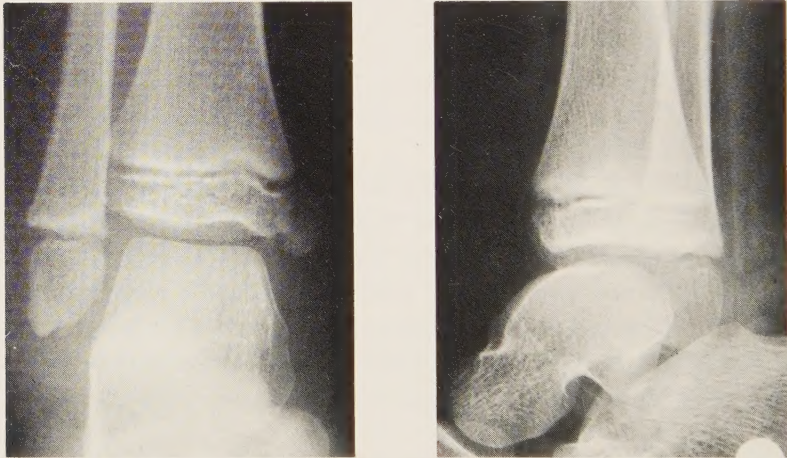


Fig. 1 Supination-adduction injury Stage IIa.

- a - AP. Physeal fracture of the distal fibula, Salter-Harris Type I. Minimal fragment at the tip of the lateral malleolus. Fracture of the medial malleolus running in a zigzag pattern detaching a minimal metaphyseal fragment (Z or Salter-Harris Type IV).
- b - Lateral.

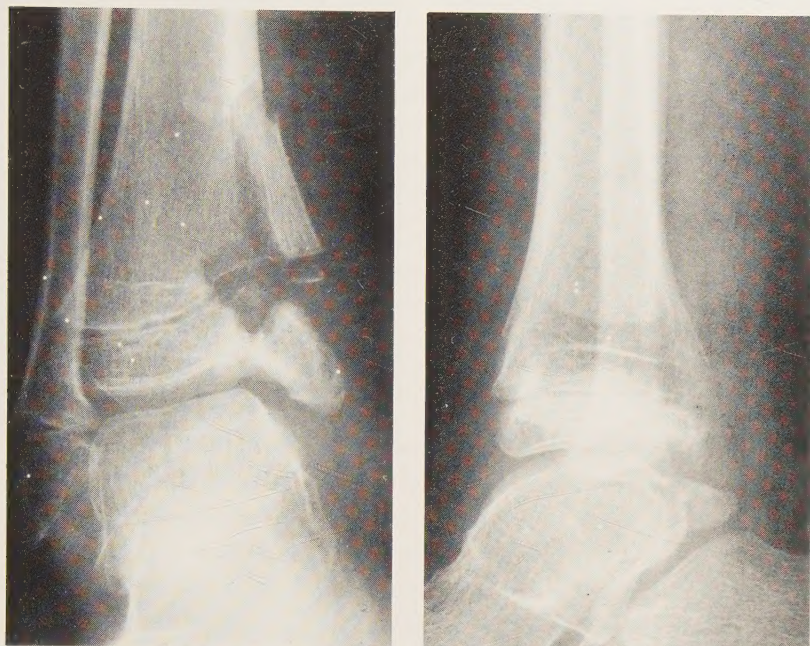


Fig. 2 Postoperative radiograms.

a - AP.

b - Lateral.

The patient developed a progressive varus deformity of the injured ankle which could be suspected radiographically about six months and was obvious twelve months after fracture.

Operation according to Langenskiöld (28,29,30) was performed about 15 months after fracture.

Postoperative radiograms (Fig. 2 a and b) documented that the bony bridge had been removed. About five weeks after the operation the patient began weight-bearing.

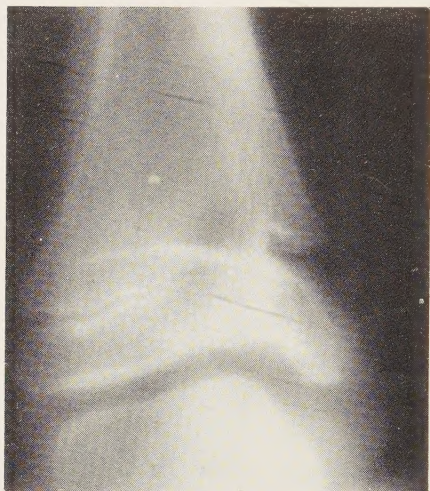


Fig. 3 a

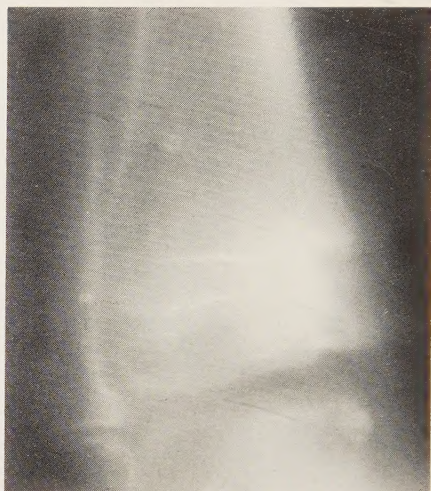


Fig. 3 b

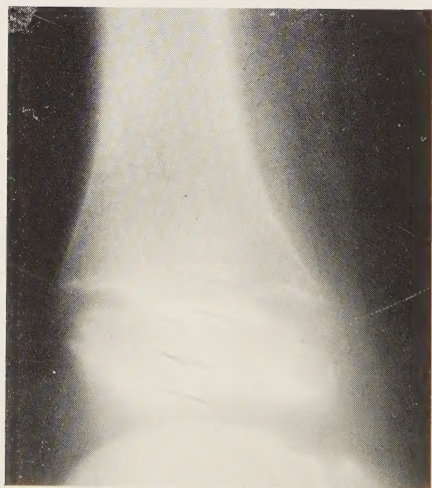


Fig. 3 c



Fig. 3 d

The patient has been followed clinically and by roentgen stereophotogrammetry 31½ months after fracture and 16 months after the Langenskiöld procedure. At the time of injury the patient was 6 years and 10 months of age; at the last examination almost 9½ years old.

RESULTS

Preoperative investigations

Tomography

Frontal tomograms (Fig. 3 a and b) 14½ months after fracture showed a bony bridge of the growth plate surrounding by a sclerosis especially in the epiphysis. A condensation line at a distance from the lateral part of the growth plate and ending at the bony bridge was visualized. Posteriorly, the medial malleolus was displaced 1-2 mm upwards forming a step in the ankle joint. The condensation line was more symmetric posteriorly than anteriorly but ended abruptly at the sclerosed region.

Lateral tomograms (Fig. 3 c and d) showed a bony bridge of the growth plate with a length of about 1.6 mm and a condensation line close to the growth plate anteriorly, but not posteriorly, as a sign of asymmetrical growth also in the sagittal plane.

Fig. 3

Frontal tomograms

- a - Anteriorly. Bone bridging of the growth plate medially. Sclerosis mainly at the epiphyseal side. Asymmetric condensation line ending in the sclerosed region.
- b - Posteriorly. More even condensation line ending at the sclerosed region. Small step at the tibial joint area.

Lateral tomograms

- c - Medially. Bony bridging of the growth plate at a distance of about 1½ cm. No visible condensation line.
- d - Laterally. Asymmetrical condensation line at a distance from the growth plate posteriorly but not anteriorly.

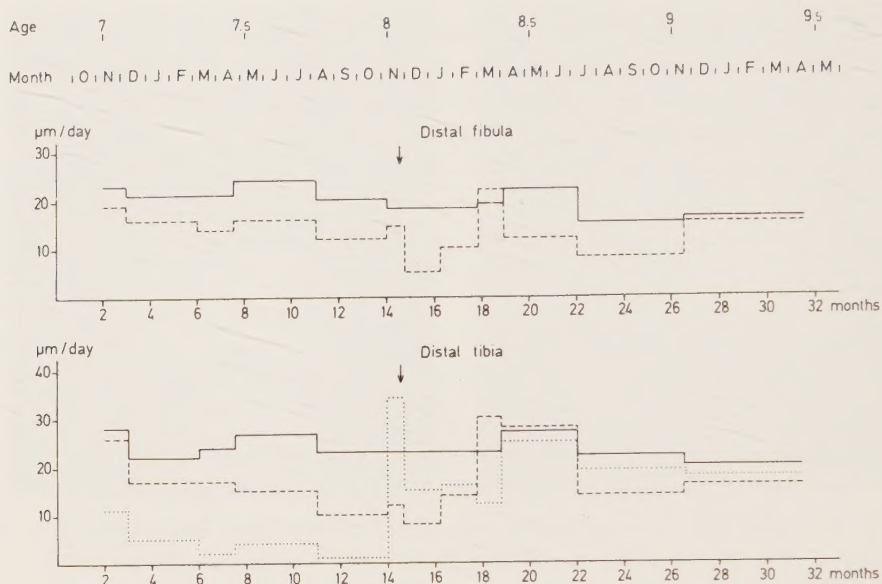


Fig. 4 Growth diagram. Top - distal fibula. Bottom - distal tibia. Above age in years and time of the year. Arrow indicates Langenskiöld operative procedure. Full line - intact side. Dashed line - fractured side distal fibula and laterally fractured side distal tibia. Dotted line - medially fractured side distal tibia.

Roentgen stereo photogrammetry

Five periods of registration between reduction of the fracture and the Langenskiöld operation: 2-3, 3-6, 6-7½, 7½-11, 11-14 months after fracture.

I. Growth analysis (Fig. 4).

In the distal tibia and fibula an initial and progressive growth retardation was registered; medially in the distal tibia the growth

rate was close to zero 11-14 months after fracture and before the Langenskiöld operation.

On the intact side the growth rates varied between 22-28 $\mu\text{m}/\text{day}$ in the distal tibia; the highest values were registered during the first period and during spring and summer months. In the distal fibula the growth pattern was rather similar but with a tendency to lower values (between 20-24 $\mu\text{m}/\text{day}$).

II. Kinema analysis (Fig. 5).

Kinema analysis showed a progressive recurvation and a varus position, which before the operation had reached about 11° , respectively.



Fig. 5 Rotational displacement of distal tibial epiphysis according to Kinema analysis. Full line - movement about transverse axis. Dashed line - movement about sagittal axis. Dotted line - movement about longitudinal axis. Arrow indicates the Langenskiöld operative procedure.

Scintimetry

Thirteen months after fracture Tc^{99m} -MDP scintimetric evaluation was performed. Quantitative analysis showed numerical ratios between fractured and intact side of 0.61 and 0.51 in distal tibia and fibula, respectively. No significant regional differences within the growth region of distal tibia were found.

Peroperative observations

Operation

At the operation during general anaesthesia and under tourniquet the periosteum was incised medially, retracted, and a part of the metaphyseal cortex (5 x 2 cm) was removed. Metaphyseal bone was removed down to the bony bridge. The metaphyseal part of the bony bridge could easily be exposed as a bud extending from the epiphysis through the growth plate into the metaphysis. Furthermore, a minimal step of the growth plate of about 1-2 mm was found. By a Michelle core biopsy instrument (6 mm diameter) the bony bridge was removed in five cylinders (central, posterior, anterior, antero-lateral, and postero-lateral). Further metaphyseal and epiphyseal bone was carefully removed until intact growth plate was surrounding the cavity. This was filled with sterile saline dressings and the tourniquet was removed. The dressings were removed after about ten minutes and the bleeding was controlled by bone wax.

An autogenous free fat transplant, with a size corresponding to the cavity, was taken at the level of the gluteal fold and inserted into the cavity. The metaphyseal bone plate was replaced and the periosteum was sutured. No plaster fixation was used.

Postoperative radiograms (Fig. 2 a and b) documented that the bony bridge had been removed.

Roentgen stereo photogrammetry

Peroperative registration period (20 days preoperatively and 1 day postoperatively).

I. Growth analysis (Fig. 4).

This examination showed that the patient had gained 0.7 mm in length medially and 0.25 mm laterally, corresponding to a movement on the average of 34 and 12 $\mu\text{m/day}$, respectively.

II. Kinema analysis (Fig. 5)

The analysis before and immediately after the operation showed mainly a reduction of the varus position; from 11° to 8° .

Histology

Longitudinal sections of the core biopsies showed that in the anterior, antero-lateral, and postero-lateral biopsies the growth plate continued through the biopsies. In the anterior biopsy (Fig. 6 a and b) accumulations of undifferentiated cartilage cells were found especially on the epiphyseal side of the growth plate. On the metaphyseal side (Fig. 6 c) there were signs of endochondral calcification and ossification, and bony islands within the cartilage. Further proximally, in the metaphysis, areas with granulation tissue and fibrosis were present and at a large area, newly formed bone and callus (Fig. 6 d). In the antero-lateral biopsy, the structure of the cartilage was more irregular and showed also an irregular transition to the bone on the metaphyseal side. In the central (Fig. 7 a), and posterior (Fig. 8 a) biopsy there were bone continuing from the epiphysis in metaphyseal direction. Small cartilaginous areas were found in the central core (Fig. 7 b); the posterior showed a more distinct cartilage bud (Fig. 8 b) protruding into the bone. The bone situated at the site of the earlier growth plate showed an irregular appearance; at the epiphyseal side it was arranged in longitudinal trabeculae. Calcified fibrous tissue (callus) was also found posteriorly corresponding to the metaphysis. Thus, in the anterior, antero-lateral and postero-lateral cores a zone of fibro-cartilage interposition was found, while in the central and posterior cores there were no signs of a cleft in the sections except the callus formation found in the most metaphyseal parts.

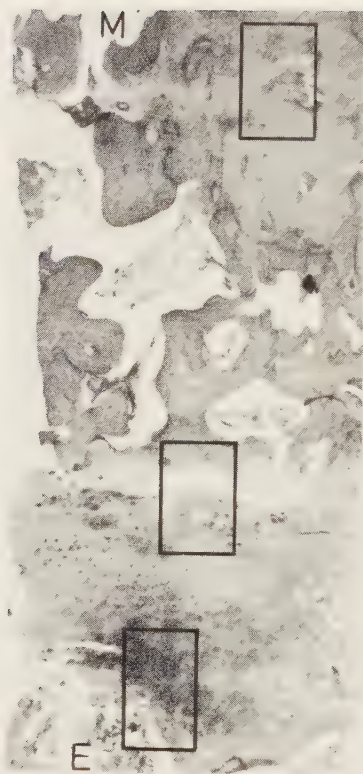
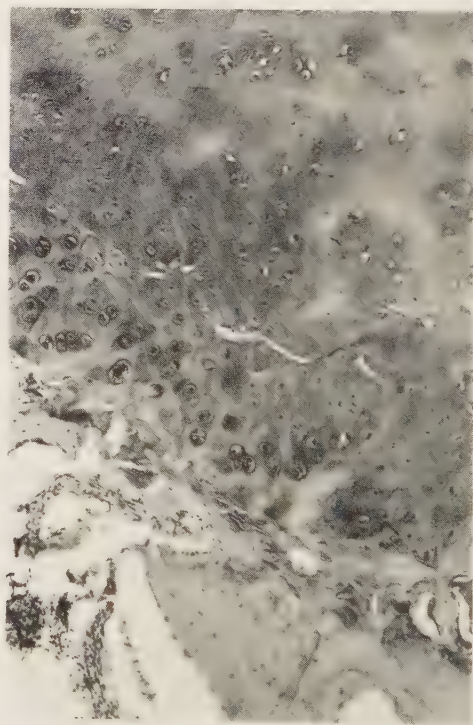


Fig. 6 Anterior biopsy.

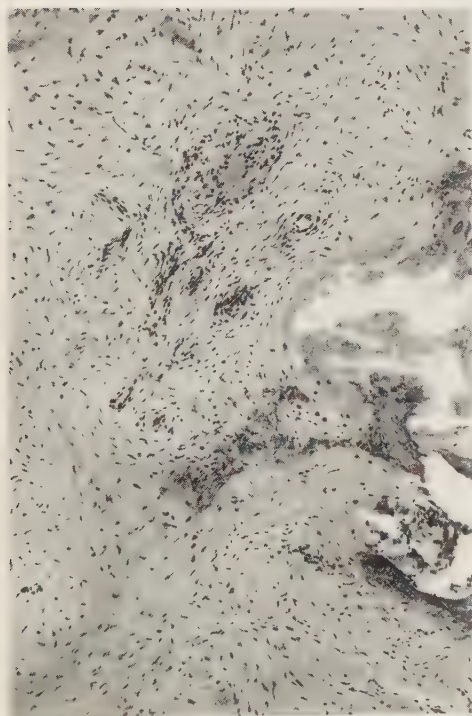
a - Growth cartilage continuing through the biopsy. At the metaphyseal side a large area with callus formation.
(x 7)

b - Accumulations of undifferentiated cartilage cells at the epiphyseal side of the growth plate.
(x 70)



c - Calcification and ossification at the metaphyseal side of the growth plate. Bony islands within the cartilage.

(x 70)



d - Callus at the metaphyseal side of the biopsy.

(x 70)

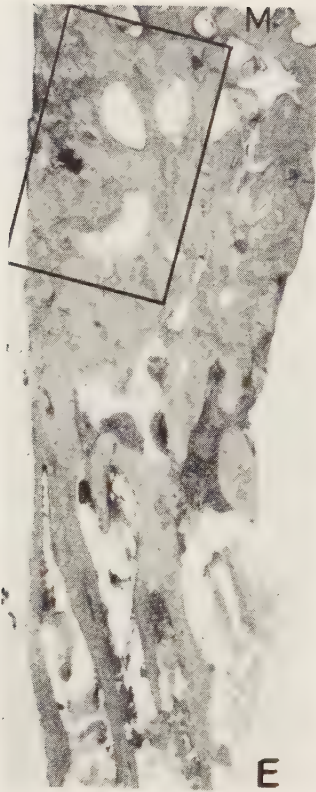
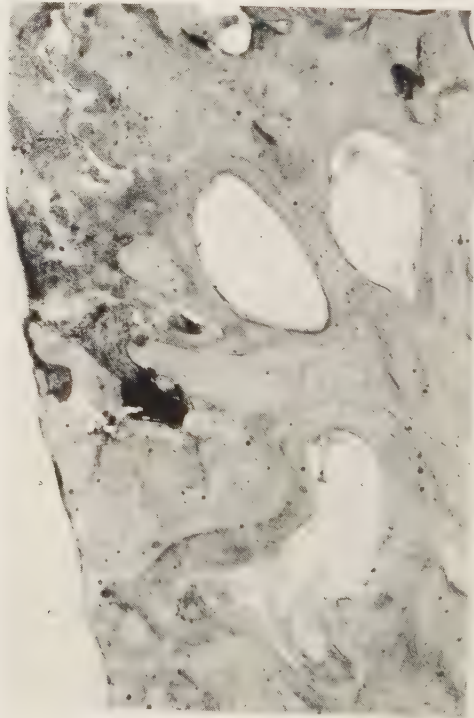


Fig. 7 Central biopsy.

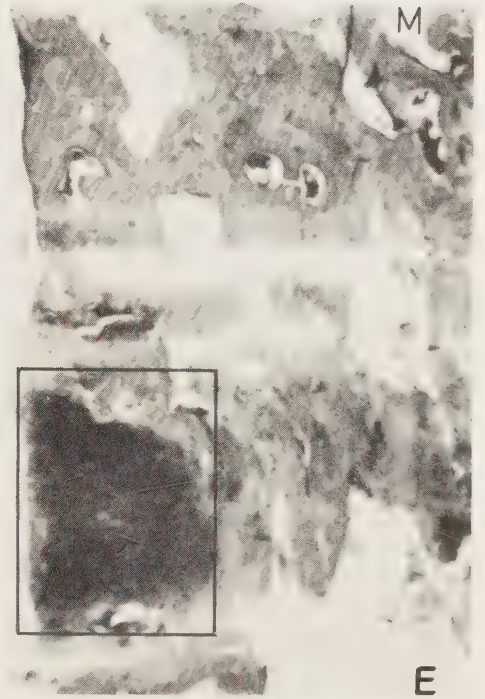
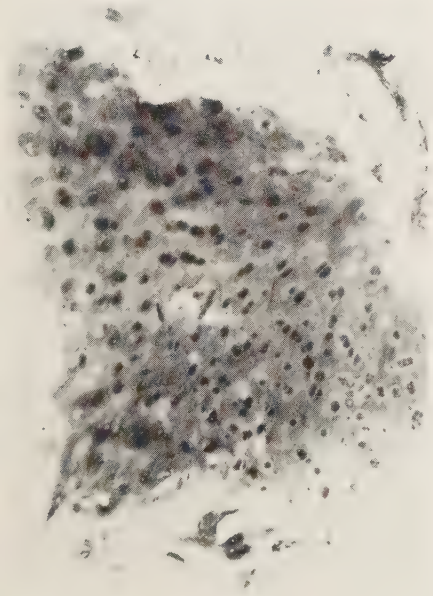
a - Bone continuing from the epiphysis in the metaphyseal direction. Small cartilaginous areas to the upper left. Longitudinal arranged bone trabeculae at the epiphyseal side. Irregular bone formation at the metaphyseal side.
(x 7)



b - Bone formation at the site of the earlier growth plate. Small area at the edge with cartilage.
(x 30)

Fig. 8 Posterior biopsy.

- a - Bone continuing from the epiphysis to the metaphysis. Small piece of the growth plate protruding into the bone.
(x **18**)



- b - Numerous undifferentiated cartilage cells.
(x **30**)



Fig. 9 Radiograms 31½ months after fracture.

a - Elongation of the fat transplant. The defect in the epiphysis no longer visible. Slight remaining varus deformity. Growth plates open.

b - Lateral.

Postoperative investigations

Radiograms 31½ months after fracture showed an elongation of the fat transplant, newly formed bone on the epiphyseal side of the defect made during the operation and a slight remaining varus deformity. (Fig. 9 a and b).

Roentgen stereophotogrammetry

Six periods of registration postoperatively: 0-2, 2-3½, 3½-4½, 4½-7½, 7½-12, 12-17, corresponding to 14½-31½ months after fracture.

I. Growth analysis (Fig. 4).

During the first two periods postoperatively the growth rate in the distal tibia was higher medially than laterally (medially: 15 and 16 $\mu\text{m/day}$; laterally: 8 and 14 $\mu\text{m/day}$), whereas higher growth rates were registered laterally during the third and fourth period (medially 12 and 15 $\mu\text{m/day}$; laterally 30 and 28 $\mu\text{m/day}$). During the fifth and sixth period the growth rate of the medial part again exceeded that of the lateral (medially 19 and 18 $\mu\text{m/day}$; laterally 14 and 16 $\mu\text{m/day}$).

In the distal fibula the growth rate decreased postoperatively to 5 $\mu\text{m/day}$ (first postoperative period). Later on, the growth rate showed similarities to that laterally in the distal tibia on the fractured side with increasing growth rates up to 22 $\mu\text{m/day}$ the third period followed by decreasing values the fourth and fifth period.

On the intact side the growth rates varied during the time of the year and were again higher during summer months. Somewhat higher growth rates were registered in the distal tibia than in the distal fibula (distal tibia: growth rates between 20 and 27 $\mu\text{m/day}$; distal fibula: growth rates between 15 and 22 $\mu\text{m/day}$).

II. Kinema analysis (Fig. 5).

During the first postoperative period the varus position was reduced to about 6° , but increased the third and fourth period to about 9° . During the fifth period again a decrease of the varus position to about 6° was registered. During the last period two of the metaphyseal bone-markers showed instability making a correct Kinema analysis impossible. Movements about the transverse axis were small during the postoperative periods.

The accumulated difference in length was preoperatively (14 months after fracture) 2.5 mm in the distal tibia and fibula, respectively. At the last registration ($31\frac{1}{2}$ months after fracture) it had increased to 5.3 mm

in the distal fibula and 8.2 mm in the distal tibia. Thus, both the distal tibia and fibula had grown less on the fractured and operated side.

DISCUSSION

There are several benefits with the Langenskiöld operation compared with osteotomy in the treatment of deformities in growing children (30).

In the present case the angular deformity was partly reduced peroperatively and during the following four months. The derotation of the epiphysis registered postoperatively could partly be because of the epiphysis, earlier subjected to a forcible medial binding, was released during the operation resulting in reduced varus deformity. The reactivation of the growing cartilage to full activity took probably several weeks corresponding to the maximum growth rates observed about four months after the operation. The high growth rates might be interpreted as a rebound phenomenon, but increasing growth rates were also observed on the intact side suggesting that a compensatory mechanism was of minor importance. The slight difference observed between the fractured and the intact side might be due to the metaphyseal trauma caused by the operation and hyperemia (21,45).

During the last period of observation higher growth rates were observed medially than laterally indicating a correction of the deformity by asymmetrical growth within the growth region and also a regeneration of the growth plate medially as was earlier experimentally demonstrated (22,34,44). Thus, the recovery took place in two steps; at first the releasing of the binding medially at the operation, later due to reactivation of growth plate. A gradual recovery of the deformity in the rabbit was sometimes also observed by Österman (48).

Radiographical examination 17 months after the operation showed that the epiphyseal defect corresponding to the removed osseofibrous bridge had

disappeared and was substituted by bone. Furthermore, there was a lengthening of the fat transplant but no bone formation at the metaphyseal side of the growth plate corresponding to the place of the osseofibrous bridge. Thus, the transplant has probably permitted a partial regeneration of the growth plate and prevented formation of a new osseofibrous bridge, as increasing growth rates were registered medially.

In the distal fibula the growth rate was lower on the fractured side all except the third and sixth period postoperatively when the growth rates were rather equal. This might be due to a compressive force transmitted from the distal tibia during some of the periods of observation, but the initial trauma might also be of importance as found in an earlier case with the same fracture type but with symmetrical growth in the distal tibia (25).

In the present study several methods such as conventional radiography, tomography, roentgen stereogrammetry, scintimetry, histology were used and could be compared. The preoperative findings on the tomograms indicated growth laterally and posteriorly according to the condensation line consistent with the data obtained from the roentgen stereophotogrammetric analysis.

Reduced scintimetric activity due to growth arrest after a physal fracture was demonstrated by Neugebauer et al. (33) and Bylander et al. (8) as found in the present case. However, quantitative analysis of the medial and lateral side in the distal tibia was rather equal not allowing a detailed examination of the growth within the growth region.

At the operation a minimal step of the growth plate was found. Österman (48) found a similar deformity and supposed this being because of lengthening and remodelling of the bony bridge. In the present case the medial malleolus might have been attached to the metaphysis and after the reduction slid upwards with the metaphysis during the initial growth. A similar deformity but more advanced has been reported in the literature (2, 11, 18). The step might also be due to incomplete reduction and healing of the medial malleolus to the rest of the tibial epiphysis.

The biopsies showed that the bridging of the growth plate mainly was constituted by bone; sometimes present as bone trabeculae, sometimes as callus. In some areas there was fibrous tissue. However, microfractures according to Johnson and Southwick (23) were not found, but the callus areas might suggest a calcification and ossification of fibrous tissue progressively reducing the longitudinal growth as registered by the roentgen stereophotogrammetric method. Furthermore, the epiphyseal bony bud protruding into the metaphysis was during the operation easily uncovered suggesting a loose fibrous connection to the surrounding parts of the metaphyseal bone and permitting longitudinal growth as registered by roentgen stereophotogrammetry. Thus, progressive growth retardation indicates a bridging of the growth plate initially constituted by fibrous tissue permitting longitudinal growth for a variable time period. During the following calcification and ossification of the fibrous scar, growth rates will be registered until a solid fusion of bone has developed between the epiphysis and the metaphysis, resulting in complete growth arrest. Thus, a pure bony bridge has not developed until complete growth arrest is registered by roentgen stereophotogrammetry. According to an experimental investigation in the rabbit (10) the growth plate may be active centrally although arrested by staples. However, the progressive nature of a physeal closure after continuous pressure was demonstrated by Trueta and Trias (46), but the dynamics of the growth plate in children might be different from those in the rabbit; especially the time table to complete physeal closure. As regards growth retardation after physeal fracture the type of growth retardation can be established about six months after fracture, but an injury to the growth plate might be disguised by an initial growth stimulation (26).

In conclusion, fusion of a growth plate due to trauma is a complex mechanism, but it is progressive if continuing more than six months after fracture (24,25). The possibility to regenerate the growth plate after a Langenskiöld operation diminishes in time. With the present knowledge of the nature of a progressive growth retardation after physeal fracture in the younger child an operative procedure in order to restore normal growth will be performed earlier when the posttraumatic growth pattern is established by the roentgen stereophotogrammetric technique.

This case report demonstrates the value of the roentgen stereophotogram-metric method which gives an early detection of a growth disturbance. The postoperative evaluation is facilitated and an eventual recurrence of the deformity will be detected.

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